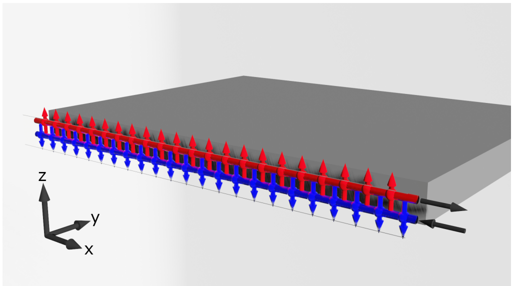
Topological edge states: colored quantum highways

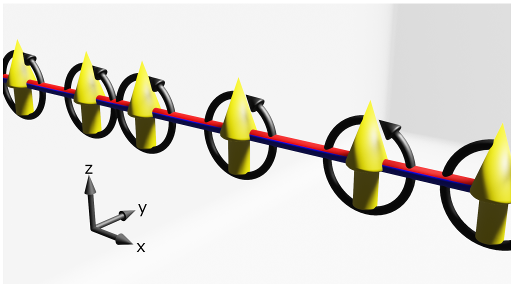
There is a huge hype about quantum computers and other types of technologies enabled by quantum mechanics at the moment. While experts are usually a bit more careful with claiming breakthroughs than the media, it is quite obvious that new materials are going to be needed. One interesting class of materials are so-called two-dimensional topological insulators. These materials exhibit dissipationless edge states, meaning they can transport electrons without losses. This alone opens huge potential while these types materials also show other interesting effects.

We can imagine an edge in this kind of system as a highway. First, we only allow blue and red cars on the highway. Secondly, cars of the same color have to go in the same direction, for example red cars to the right and blue cars to the left, as illustrated in Fig. (A). If it is a perfectly straight and flat road all cars will go at the same speed and that very efficiently. If there are some markings on the road, some people might think: "oh, maybe I'll go slower", while others feel like "ok, I'll look out, but in the meantime let's speed up a bit". In the end, we will have a lot of cars going at slightly different speeds.

So far this model does not feel too weird, but we can now imagine that all the cars have a little arrow on the dashboard, representing the so-called spin of the electrons. If that arrow points upwards the car is red, if it points downwards it is blue. Now, since the car changes color if the arrow flips, it also has to change it's direction and drive on other side of the highway. This is a simple picture of the physical term "spin-momentum-locking": the direction of the movement (color) is linked to the orientation of the spin (arrow).



(A) Edge channels carrying different spin species (red/blue) on the edge of a 2D material.



(B) Randomly placed, aligned rotating magnetic impurities (yellow) on the 1D Edge channels (red/blue).

But what happens if we have speed bumps instead of the markings? Now the arrows might flip and then the car changes its color and has to change its direction. The effect of magnetic impurities corresponds to the speed bumps possibly changing the direction of the arrow on the dashboard! It is already rather impractical to have speed bumps on a highway, but now imagine someone decided it might be a good idea to let the bumps change their height, letting them emerge from the ground periodically. That corresponds to rotating magnetic impurities, illustrated in Fig. (B) and the effects of this are main focus of this thesis.

But why would we even need these kind of electron highways? For example, we could need spin-filters that only let one spin-species, i.e. one color of cars, pass. Maybe we even want a special setup of speed bumps (intentional impurities, doping) or we have some pot holes (unintentional impurities) and need to know what that does to our system. These and more applications make two dimensional topological insulators a class of materials, we might hear a lot about in the future.

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